



# Matsu: An Elastic Cloud Connected to a SensorWeb for Disaster Response

(Session 12F Working Group: **Cloud Computing for Spacecraft Operations**)

Daniel Mandl - NASA/GSFC

3/2/11

A red-bordered banner for the "Ground System Architectures Workshop".

**Ground System  
Architectures Workshop**

**"Harmonization: Challenges and Opportunities"**

Sheraton Gateway Hotel, Los Angeles

February 28–March 3, 2011

**AEROSPACE**  
Assuring Space Mission Success

1

# SensorWeb High Level Architecture

floods, fires,  
volcanoes etc



## Data Processing Node

SensorML  
Capabilities  
Documents

Web  
Coordinate  
Transformation  
Service  
(WCTS)

Web  
Processing  
Service  
(WPS)

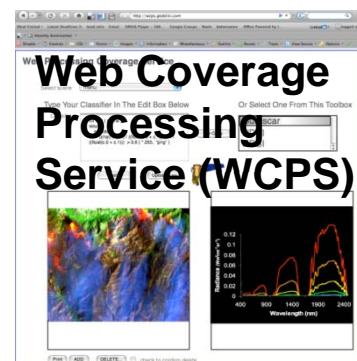
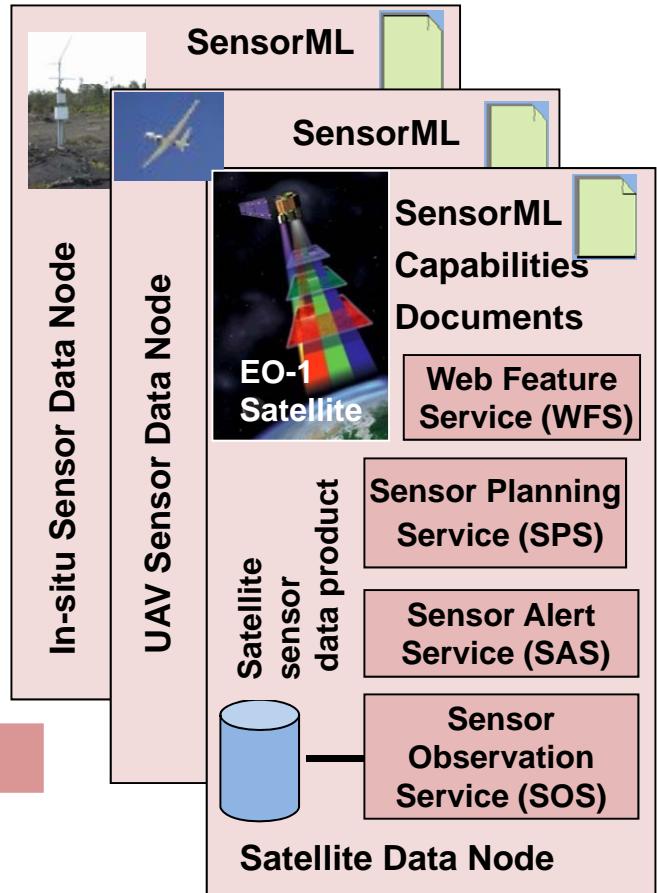
Web  
Coverage  
Service  
(WCS)



Sensor  
Data  
Products

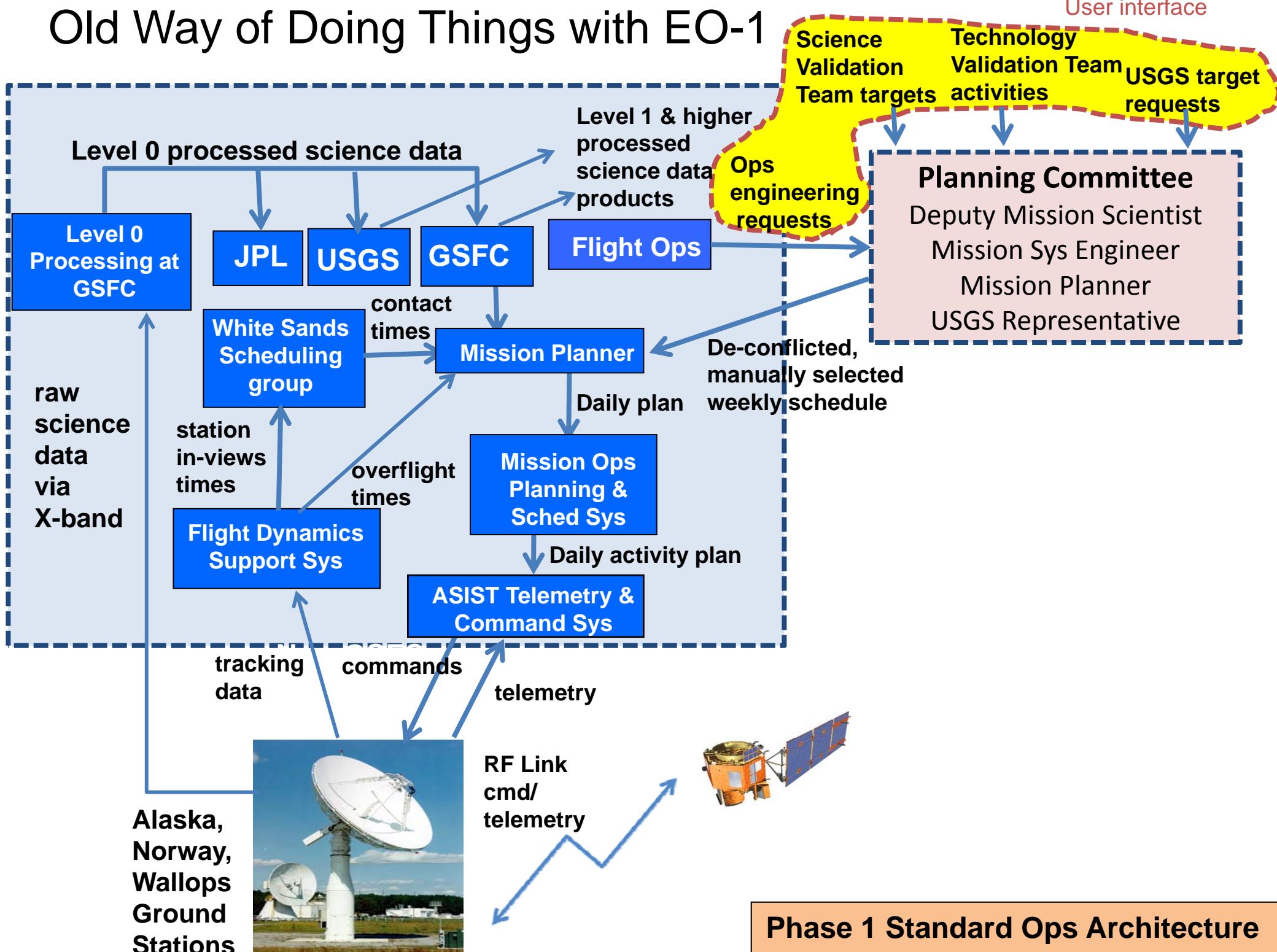
Internet

OpenID 2.0

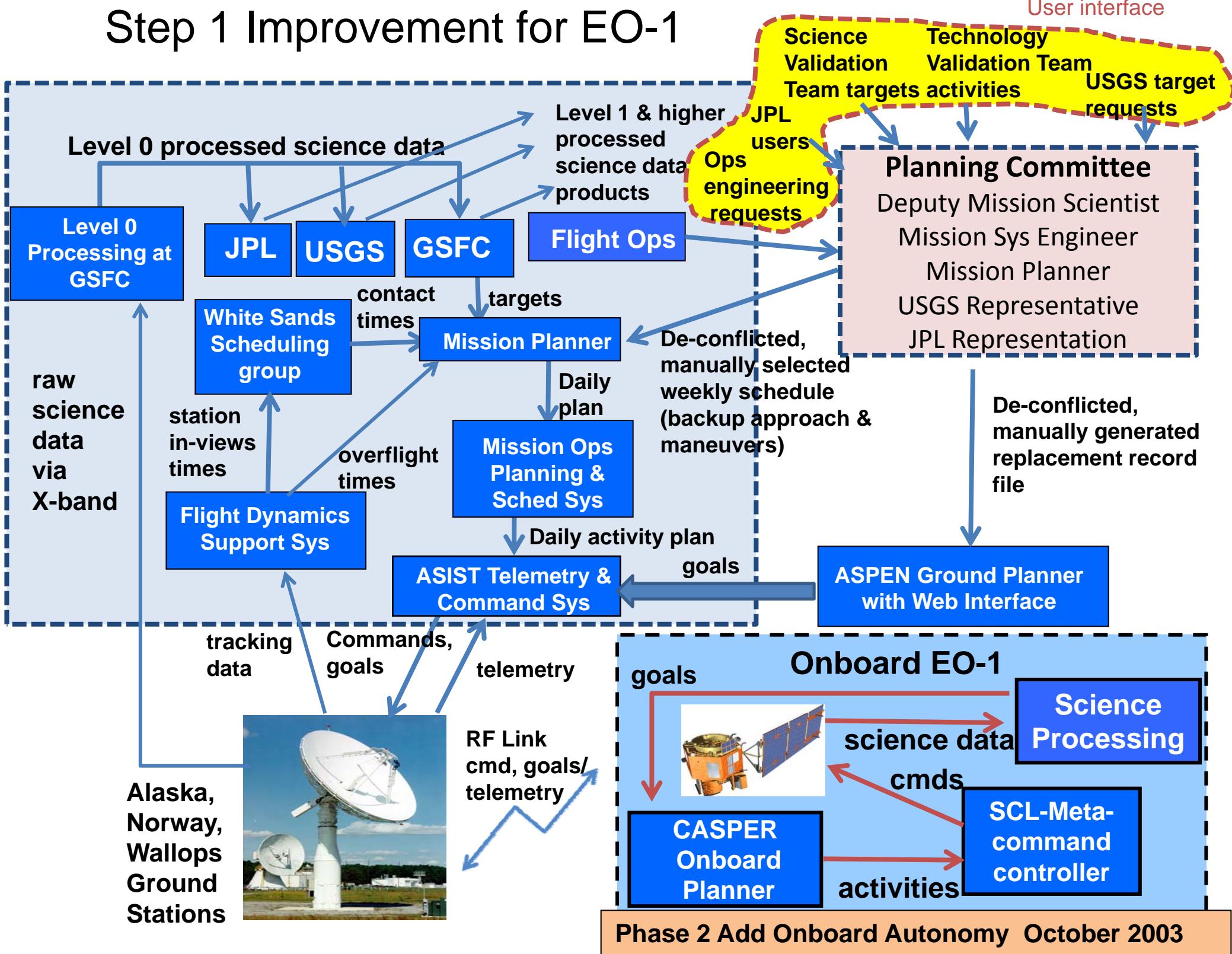


Workflows

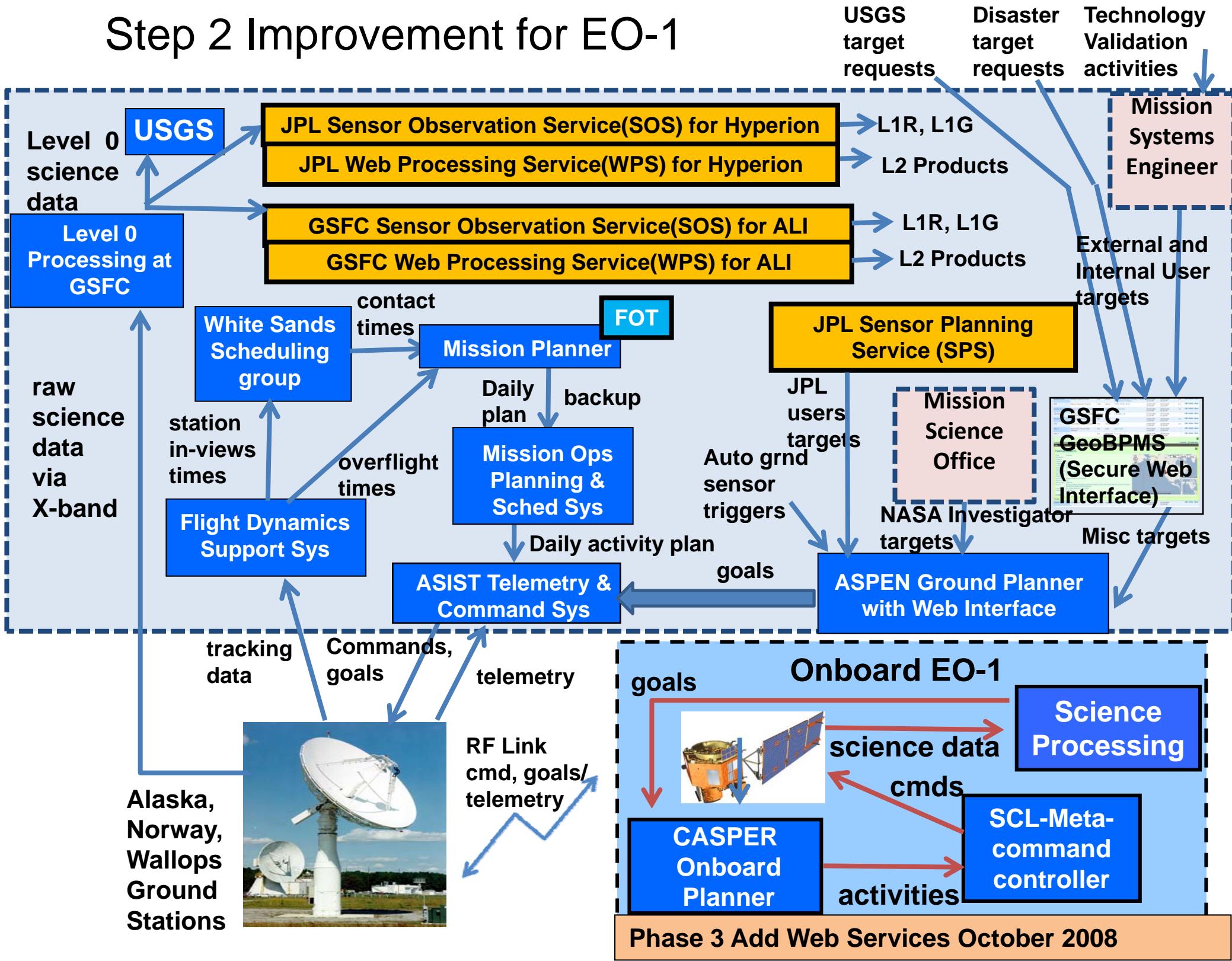
# Old Way of Doing Things with EO-1



# Step 1 Improvement for EO-1



# Step 2 Improvement for EO-1

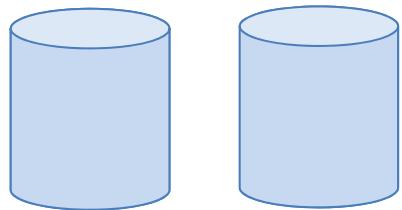




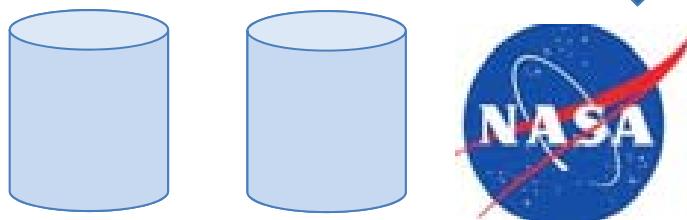
Open Cloud  
Consortium



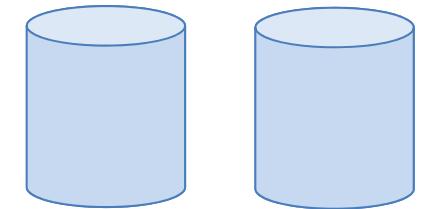
Open Science  
Data Cloud



Biological data  
(Bionimbus)



**STARLIGHT**<sup>SM</sup>  
The Optical STAR TAP<sup>SM</sup>

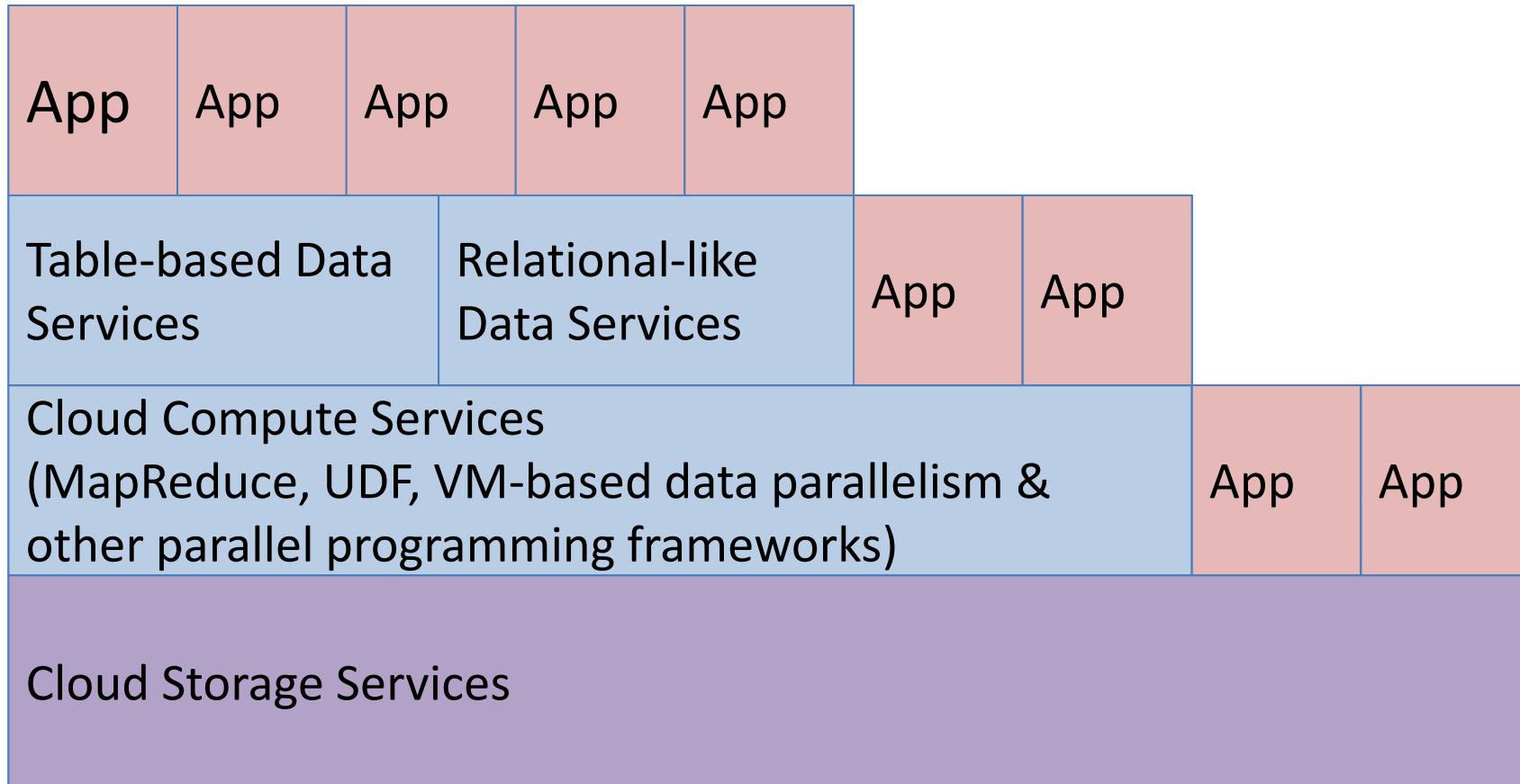


Astronomical data



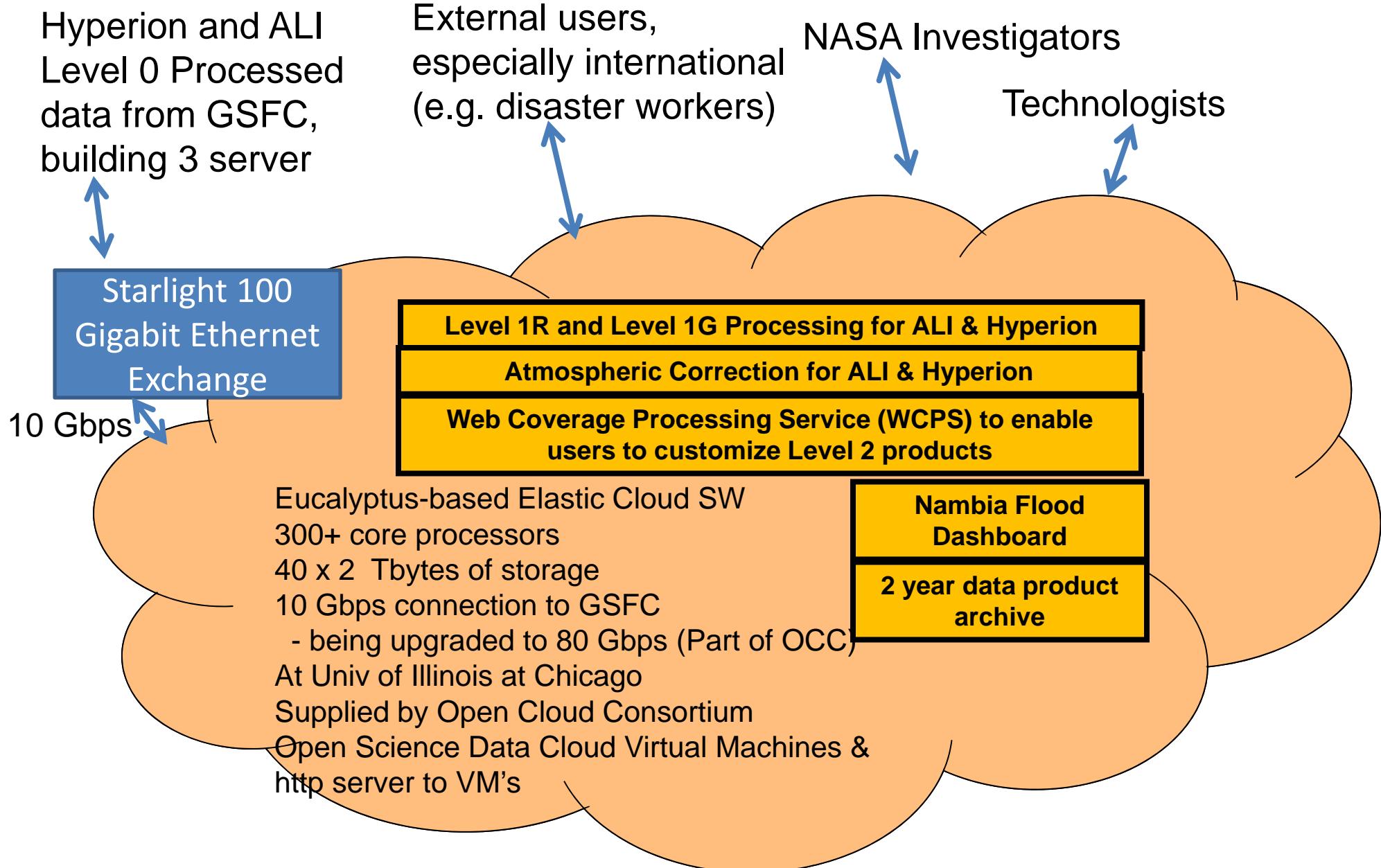
NSF-PIRE OSDC Data Challenge

# Focus of OCC Large Data Cloud Working Group



- Developing APIs for this framework.

# Step 3 Improvement for EO-1 - Overview

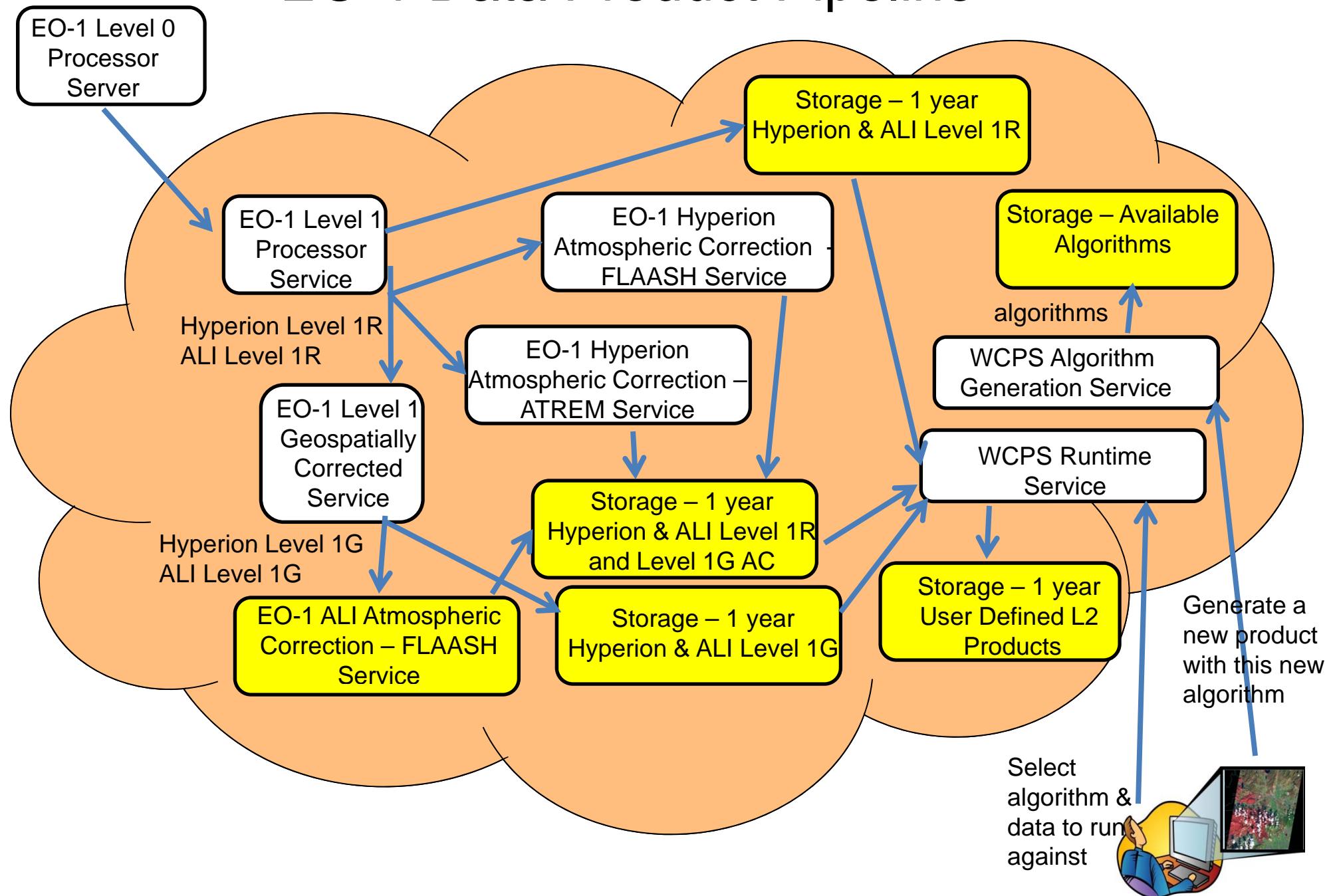


OCC = Open Cloud Consortium

Phase 3 Add Elastic Cloud Ongoing Feb 2011

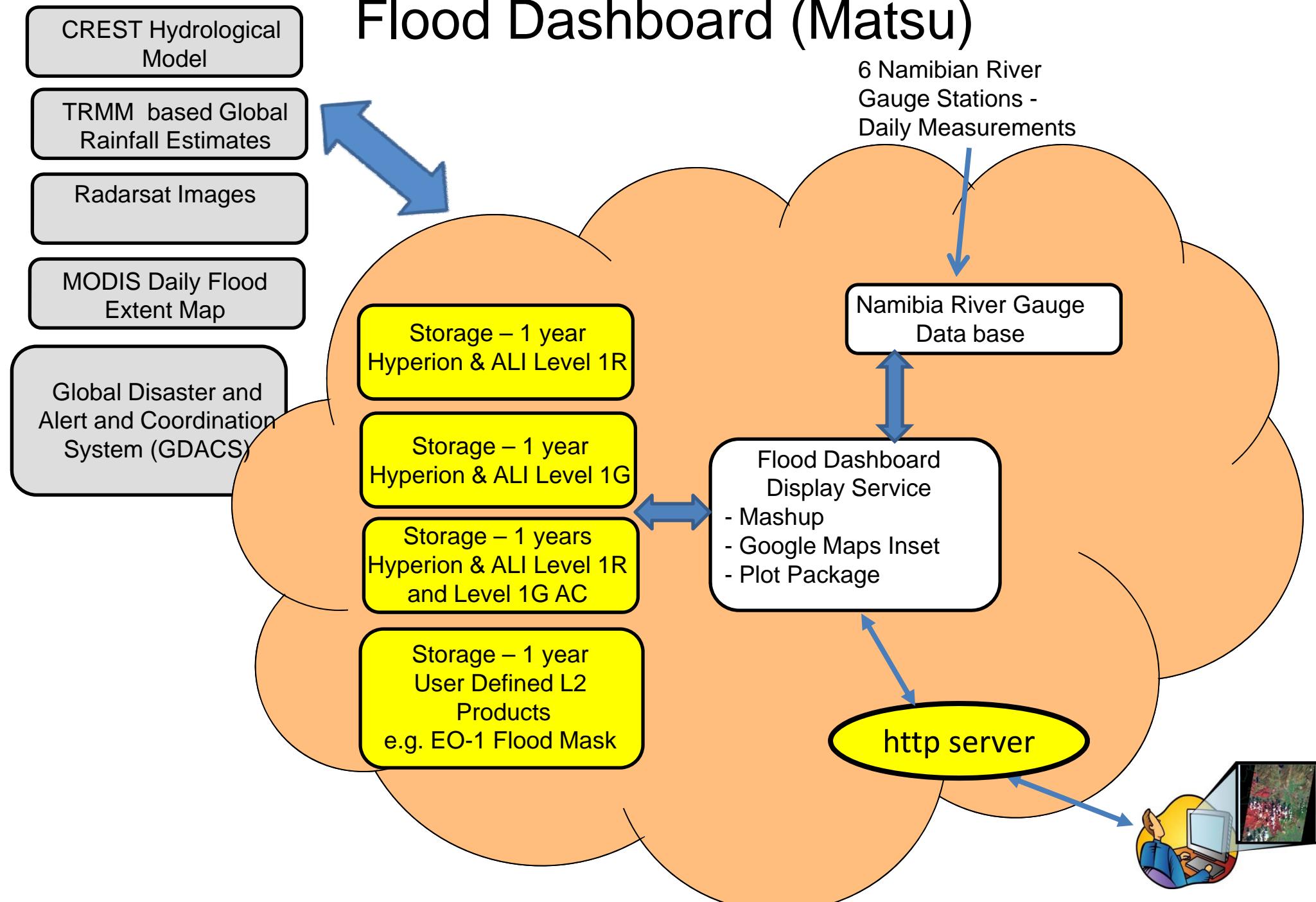
# Transformation to On-Demand Product Cloud Part 1

## EO-1 Data Product Pipeline



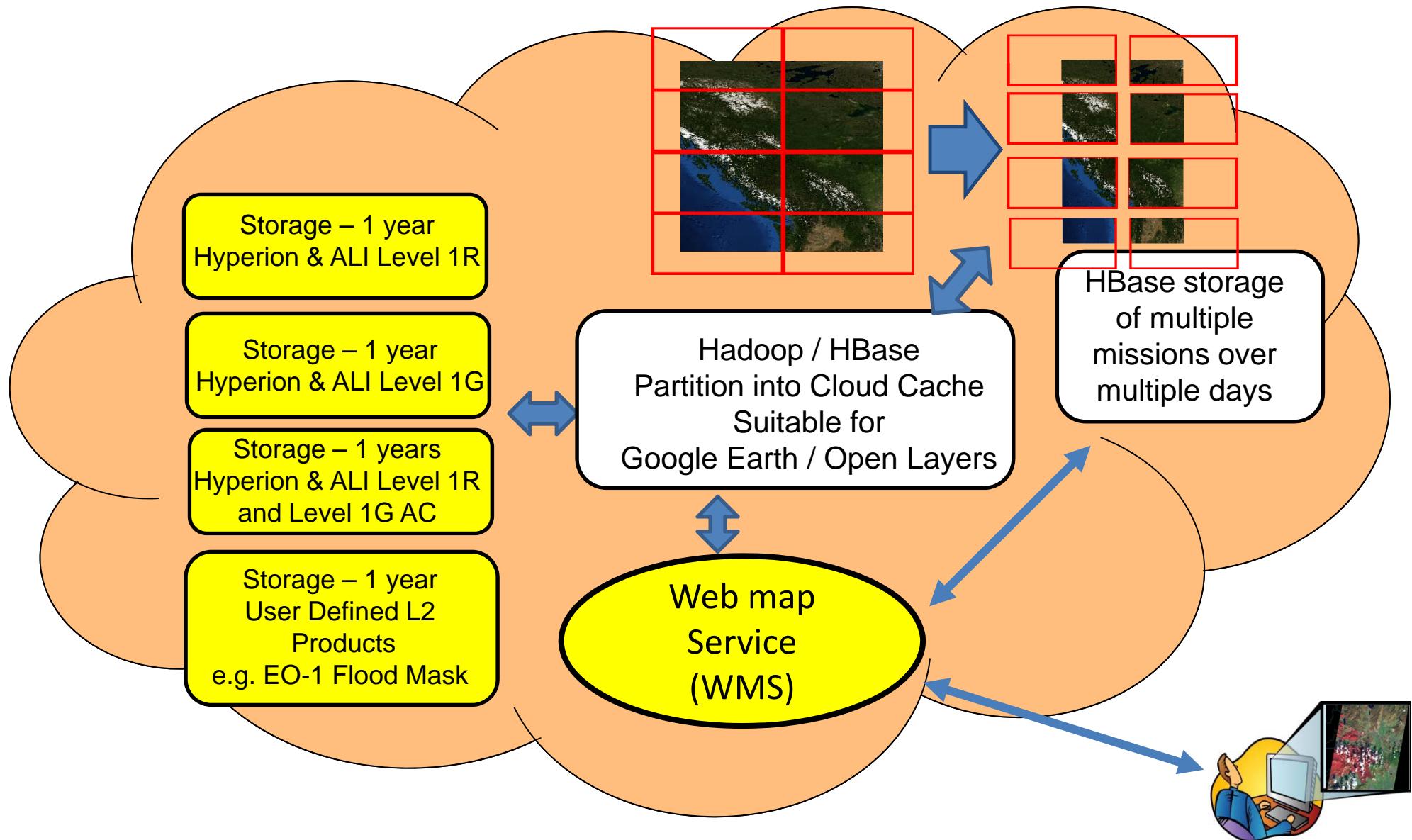
# On-Demand Product Cloud Part 2

## Flood Dashboard (Matsu)



Phase 3 Add Elastic Cloud Ongoing Feb 2011

# Detail of Processing Image Data in OCC Open Science Data Cloud



# Top Level Flood SensorWeb Concept



Manual or automated triggered requests for satellite imagery in area of interest



GeoBPMS – Web based satellite tasking tool

Customized plan of needed satellite images



SPS

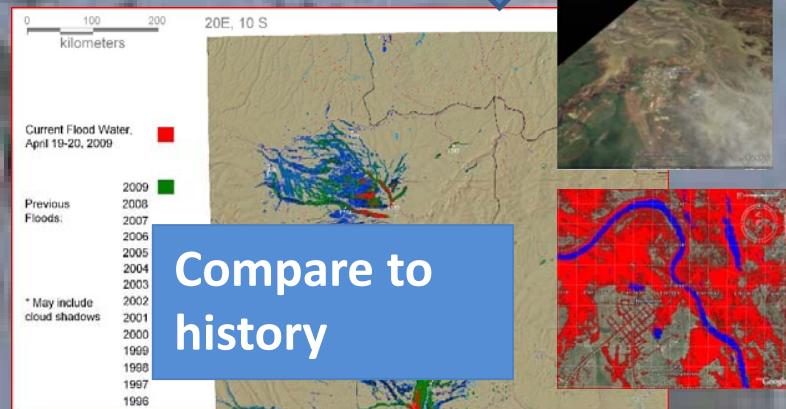


SPS

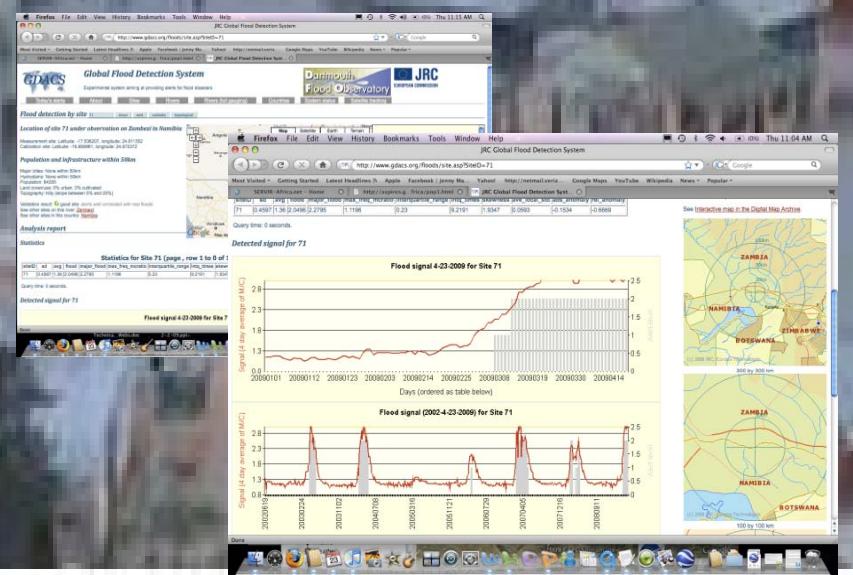
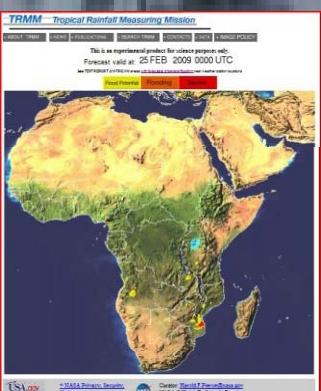


SPS

Flood conditions



Compare to history



Improved flood prediction model

\*SPS = Sensor Planning Service

# Portion of 2011 Namibian Flood SensorWeb Early Warning Pilot



Angola

Namibia

**Shanalumono  
River Gauge Station**



**Oshakati**

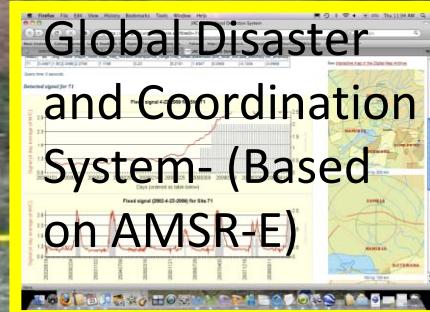
**Water flow from  
North through basin**

**Ongwediva**





Early user alert



Shanalumono River Gauge Station



Auto triggers



Auto-trigger Hi-res Satellite images



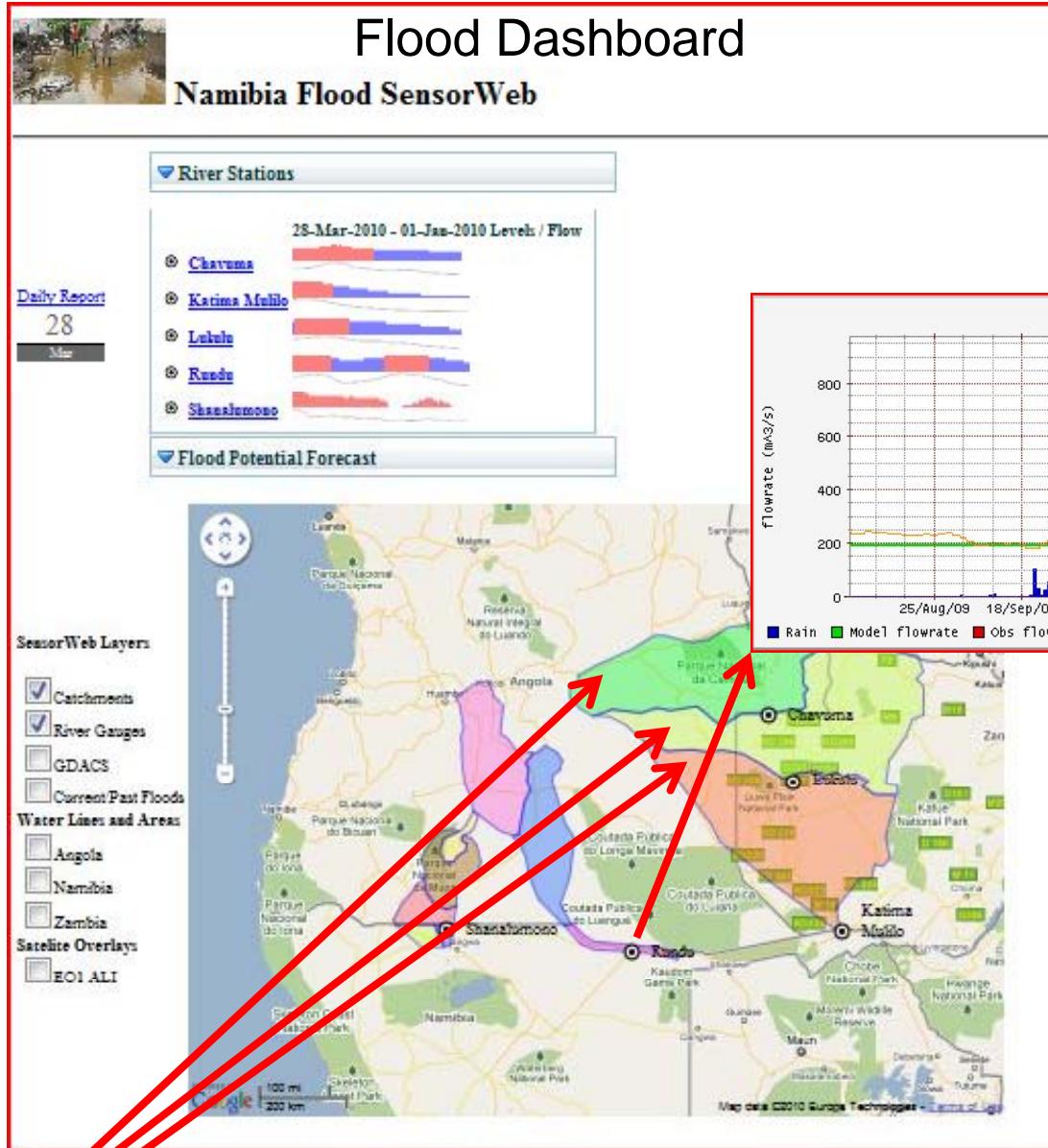
Daily flood gauge levels & predicted river levels plots

Ongwediva

Oshakati

Portion of 2011 Namibia Flood SensorWeb Early Warning Pilot:

# Experimental Namibian Flood SensorWeb Webpage



Note blue bars indicating a surge of rainfall upstream

Then a flood wave appears downstream at Rundu river gauge days later

## Namibia Short Term Pilot for 2010

- Colored areas represent catchments where rainfall collects and drains to river basins
- River gauges displayed as small circles
- Detailed measurements are available on the display by clicking on the river gauge stations.
- This display can be viewed and manipulated at:

<http://geobpms.geobliki.com/namibia>  
and  
<http://geobpms.geobliki.com/namibia2>

Zambezi basin consisting of upper, middle and lower catchments

# Shanalumono River Gauge Station and Part of Community Prone to Flooding Downstream



# Experimental Namibian Flood SensorWeb Webpage

## View of Available Envisat & EO-1 Overlay Images

### Flood Dashboard

### Namibia Flood SensorWeb

[Daily Report](#)  
25  
Apr

[River Stations](#)

[Flood Potential Forecast](#)

[1-Day Flood Potential Forecast](#)

[5-Day Flood Potential Forecast](#)

[Severe Flood Report](#)

**SensorWeb Layers**

- Catchments
- River Gauges
- GDACS
- Current/Past Floods

**Water Lines and Areas**

- Angola
- Namibia
- Zambia

**Dwelling Density**

- Northern Namibia

**Satelite Overlays**

- EO1 ALI
- SAR (SRI/Ukraine)

**2010-01-30 Flood Water Area**  
Flood/water mask derived from SAR imagery  
Image credit: Copyright ESA 2009, 2010  
Image processing, map created by:  
Space Research Institute,  
National Academy of Sciences of Ukraine,  
National Space Agency of Ukraine.

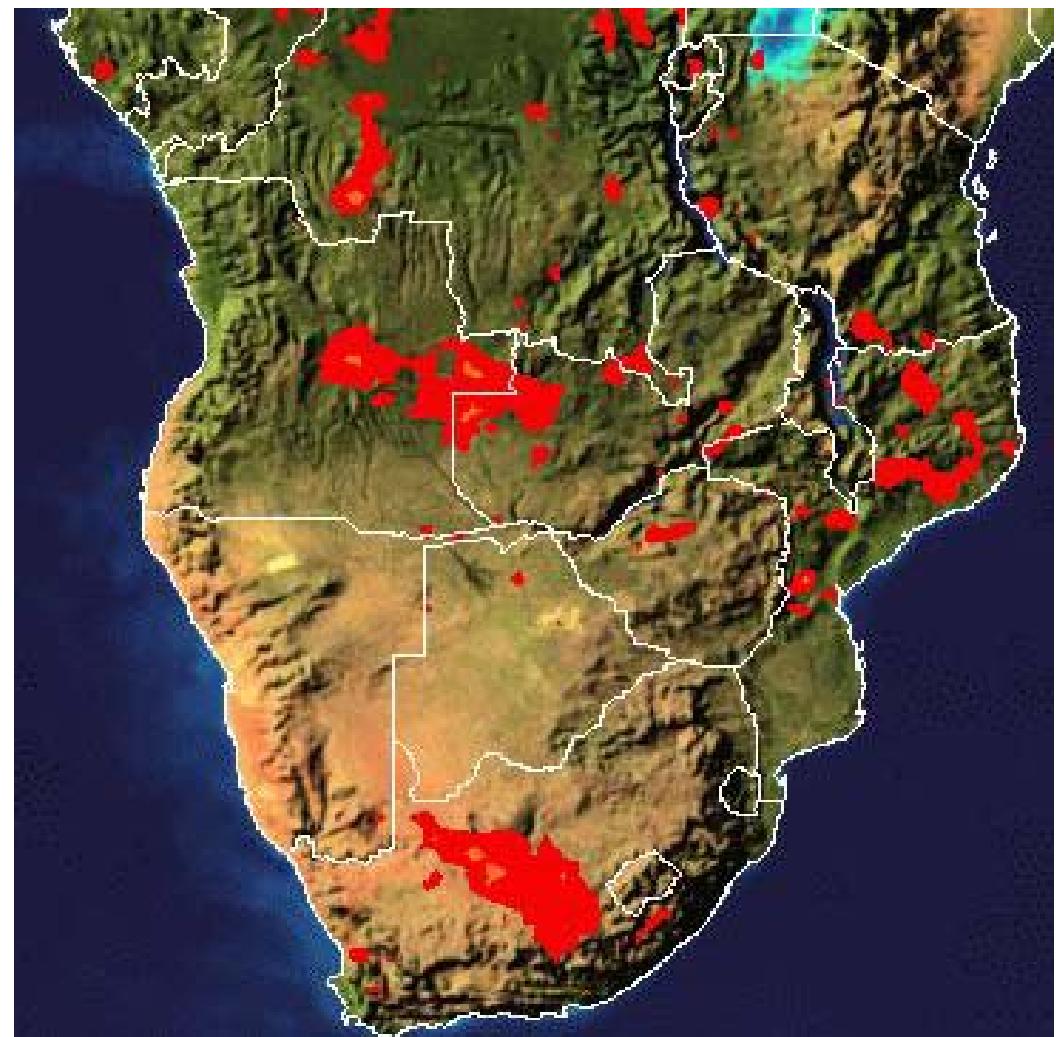
2010-03-28 (07:58 UTC)  
[Download KML file](#)

**Experimental TRMM-based Flood Forecast Products**

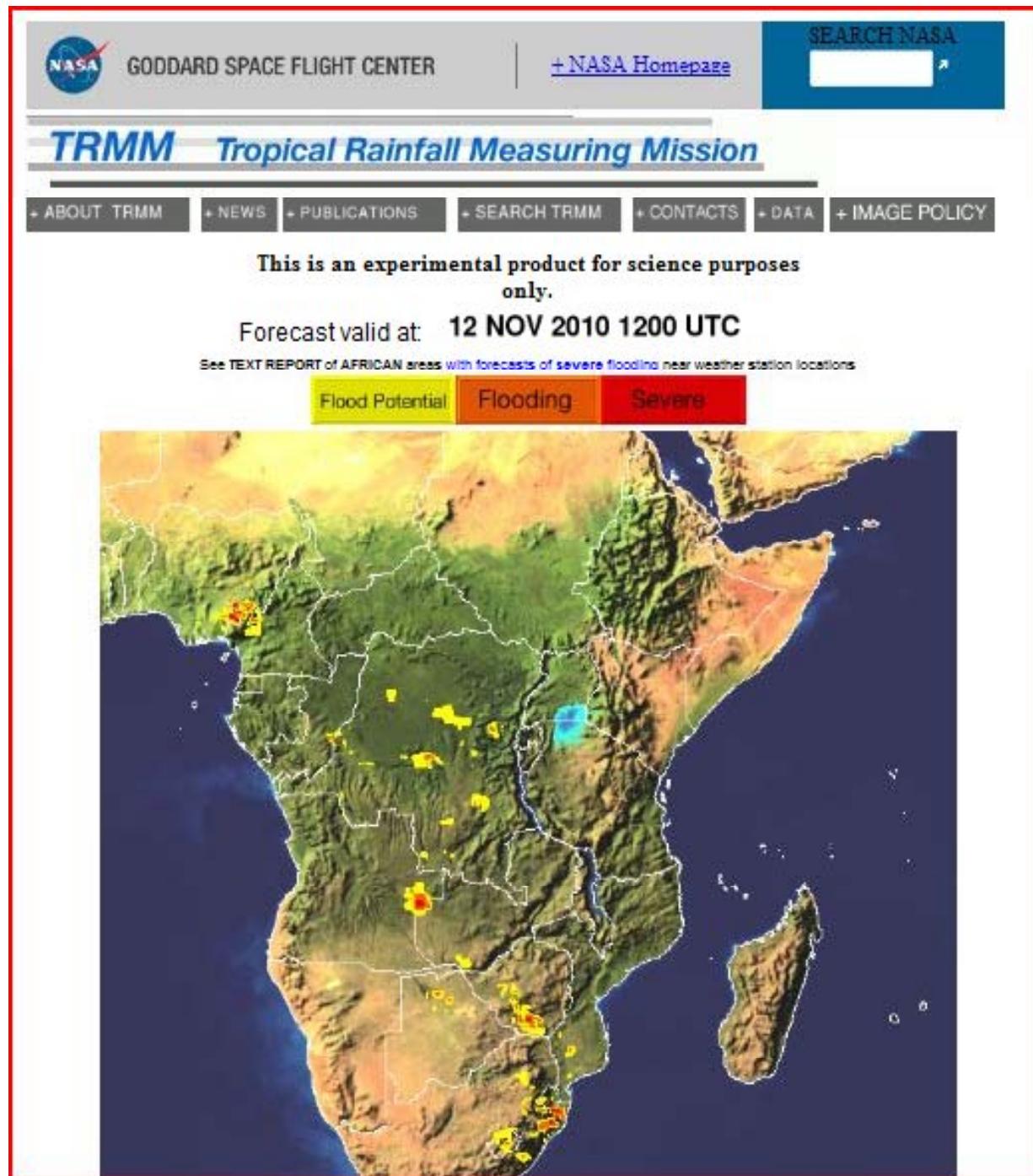
**Envisat SAR and EO-1 Optical Image Overlays**

# Estimated Rainfall Webpage Based on TRMM Data

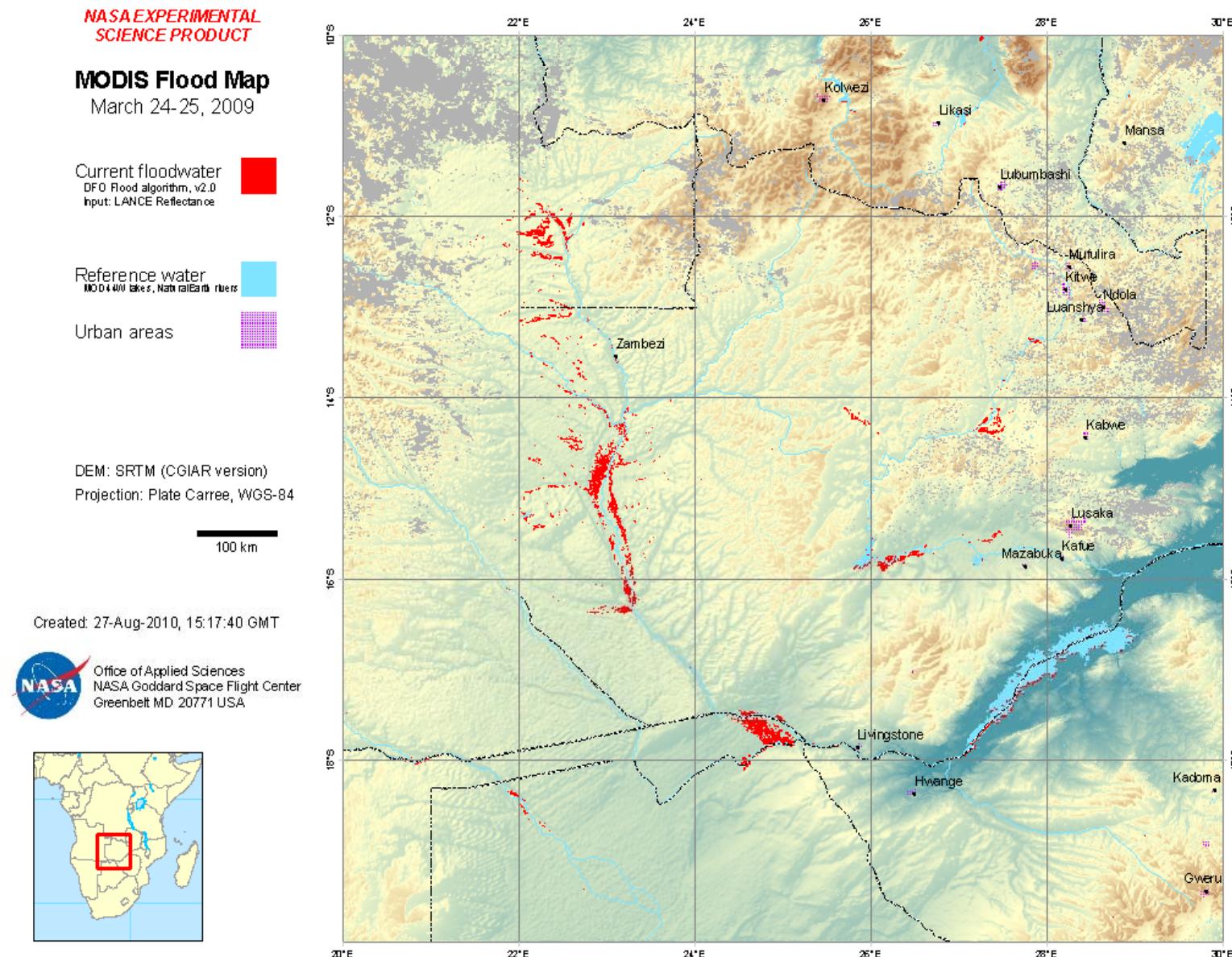
- Experimented with various hydrometeorological information for flood forecasting models
  - remote sensing
  - rainfall estimates
  - 24 February 2010
  - NASA Servir Africa
  - red is  $> 35$  mm



# Experimental Global TRMM Based Flood Forecast

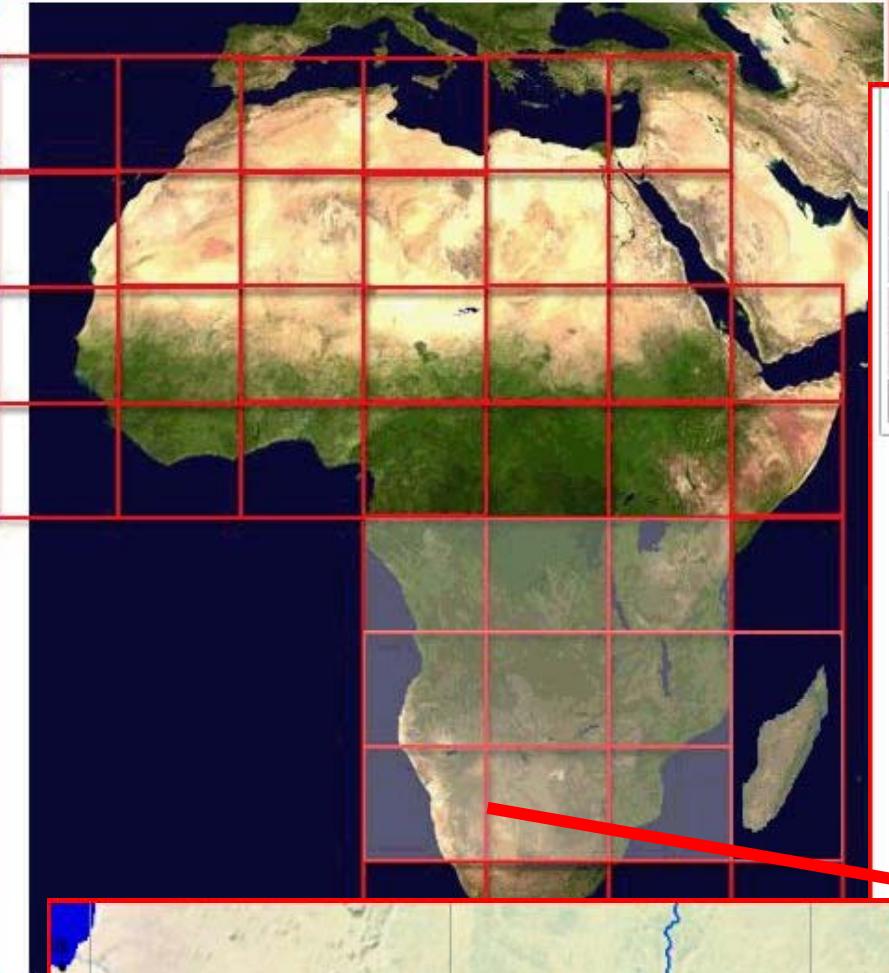


# Experimental Flood Extent Data Product Derived from MODIS



First product out of automated MODIS flood extent map pipeline prototype. Used data from March 2009 when large floods occurred to test.

# Recent MODIS Daily Flood Extent



Su	Mo	Tu	We	Th	Fr	Sa
					1	
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Area toured on January 2011 trip

NASA EXPERIMENTAL  
SCIENCE PRODUCT

MODIS Flood Map

29-30 Jan 2011

Tile 010E010S

Current floodwater  
MODIS-derived

Cloud  
MODIS-derived

Reference water  
MODIS-derived  
Water bodies

Urban areas

Background  
MODIS World Physical Map

100 km Projection: Pseudo-Cylindrical, WGS84

Product of MODIS-derived  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771 USA

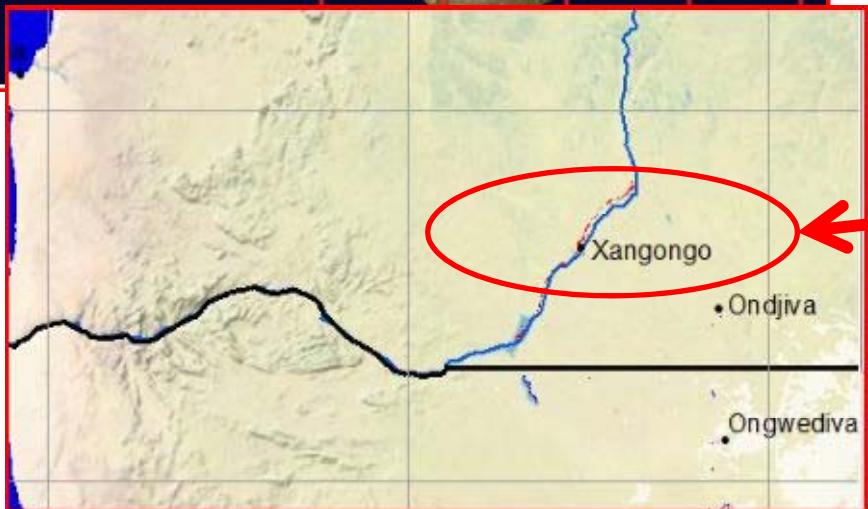
Color: RGB  
Lat/Long: 010E010S

Generated: 30 Jan 2011 12:27:45 GMT

Colorbar: RGB  
Lat/Long: 010E010S

Generated: 30 Jan 2011 12:27:45 GMT

Recent  
flooded area



# Sample of Planned Addition of Higher Resolution Flood Product Overlay Using EO-1

## EO-1 Land Cover Land Use Change

ALI Imagery of Australian Flood (Mar. 2009)



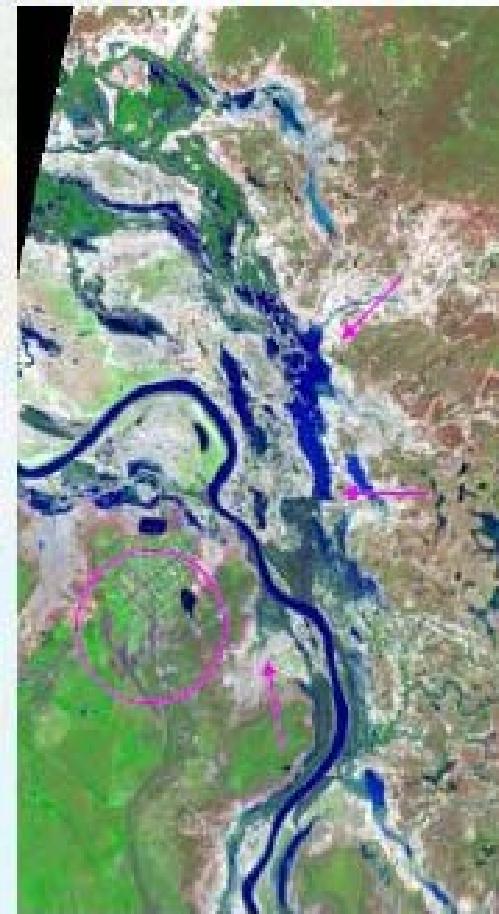
March 12, 2009  
True-Color Image  
EO-1 ALI Image

In this true-color image, note how the water color is so muddy that it makes discerning the extent of the flooding difficult.



March 12, 2009  
False-Color Image  
EO-1 ALI Flood Product

This false-color image combines infrared and visible light, which makes the extent of the flooding far more obvious. Water is dark blue, while plant-covered land is green, and bare earth is rosy tan.



March 25, 2009  
False-Color Image  
EO-1 ALI Flood Product

Two weeks later, the flood waters have receded even more, which the EO-1 Flood Product makes evident.

# Mashup of Satellite Data and River Gauge Data Using Namibia2 (Google Earth Version) Webpage Tool

**Places**

- Liambezi-Radarsat 3-25-09.k...
- Liambezi Radarsat 5-20-09.k...
- Liambezi Radarsat 5-22-09.k...
- Liambezi Radarsat 5-29-09.k...
- Liambezi Radarsat 5-30-09.k...
- EO-1 Lake Liambezi Pan Sha...
- EO-1 Lake Liambezi Tour M...
- 1
- 2
- Chobe Inlet
- Photo 4 - Chobe inlet
- Lake Edge

**Layers**

- Primary Database
- Borders and Labels
- Places
- Panoramio Photos
- Roads
- 3D Buildings
- Ocean
- Street View
- Weather
- Gallery
- Global Awareness
- More

**Envisat swath**

**EO-1 Data March 2009**

**Radarsat Data March 25, 2009**

**Envisat Data March 2009**

**Zambia water lines from old database**

**Lower Zambezi catchment**

**Multiyear river gauge measurements**

NORMAL, 2009 AND 2010 WATER LEVELS AT KATIMA MULILO - UPDATE 23 FEBRUARY 2010

Date	Normal (m)	2009 (m)	2010 (m)
1-Jan	0.500	0.500	0.500
21-Jan	1.500	1.500	1.500
10-Feb	2.500	2.500	2.500
2-Mar	3.500	3.500	3.500
22-Mar	4.500	4.500	4.500
11-Apr	5.500	5.500	5.500

# Mock up of Revised River Gauge Plot Page

## River Station - Station 1

Period: To: 1/1 From: 4/31

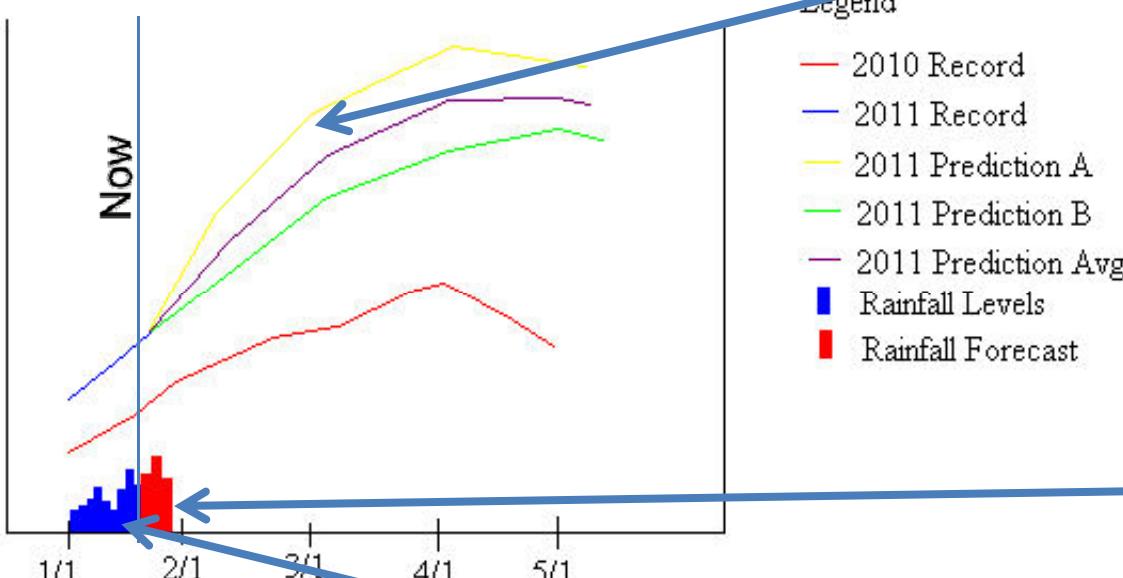
Series Station ID Year Color Legend

1 1 2011 ↓ blue ↓ 2011 Record

2 1 2010 ↓ red ↓ 2010 Record

3      ↓      ↓

Title: My Graph



Various flood models such as  
CREST model (Univ. of Oklahoma)

Rainfall prediction  
From GEOS-5

TRMM based daily  
rainfall estimates

Station CSV

# Sample Display of Multi-year Satellite Measurements (in month of March) of Katima Mulilo Linked to JRC Via Namibia Flood Mashup Based on Terra AMSR-E Microwave Instrument

**GDACS Global Flood Detection System - Version 2**

An experimental system to detect and map in near-real time major river floods based on daily passive microwave satellite observations. The purpose is to identify and measure floods with potential humanitarian consequences after they occur.

Home Current floods Global map Search areas Custom areas Animations Download About

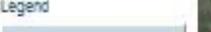
**Create a customize graph by parameter**

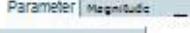
You can create a custom graph combining up to 4 time series. In a given time period, you can compare different sites (e.g. upstream, midstream, downstream for flood propagation) and/or different years (e.g. comparison with last year's floods). Available parameters are: flood signal (ratio of brightness temperature of observation and nearby dry pixel), flood magnitude (signal anomaly expressed as standard deviation removed from the mean) and estimated flooded area (in km<sup>2</sup>).

Area Id: 14950 Colour: Red Legend: 

Period: From 2010-02-01 To 2010-09-19

Series: AreaId Year Colour Legend

1.	14950	2009	Green	
2.	14950	2008	Blue	
3.	14950	2007	Black	

Parameter: Magnitude 

Title:



**Katima Mulilo (DWAF) (14950) from 2010-02-01 to 2010-09-19**

Magnitude

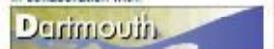
2/1/2010 3/1/2010 4/1/2010 5/1/2010 6/1/2010 7/1/2010 8/1/2010 9/1/2010

Legend:

- Magnitude in site 14950 for 2010
- Magnitude in site 14950 for 2009
- Magnitude in site 14950 for 2008
- Magnitude in site 14950 for 2007

Please note that the information provided on this website has no official status and does not replace local flood warnings. Please refer to the competent local hydrographic authorities for official information on the flood status in each country.

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In collaboration with: 

# Sample Alert During Pilot

**Namibia daily flood bulletin 03 March 2010:**

There have again been heavy rains in parts of the Zambezi catchment. See attached NASA map. The waterlevels at Chavuma started rising again. See attached graph. Our forecast remains that the Katima Mulilo waterlevels are heading for 7 m by mid-March 2010. For perspective, the flood would be:

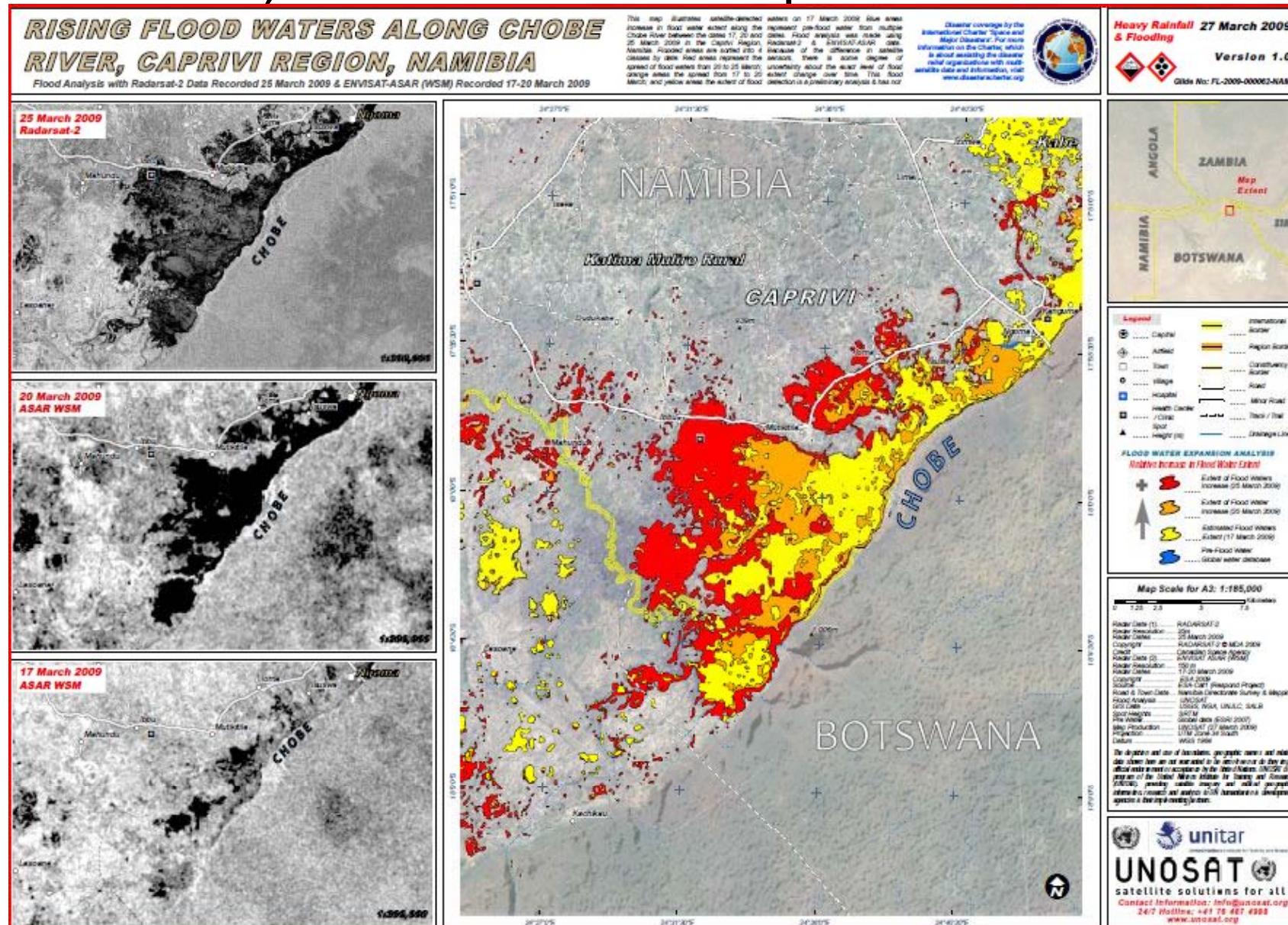
**similar to 2007**

**higher than 2008**

**lower than 2009**

But much will depend on the rains and the catchment response in the coming weeks.

# Sample Time Sequence Flood Map Generated by Unosat, Derived from Multiple Satellite Data Sets



Vision is to generate similar product automatically when floods predicted and pair them with river gauge measurements

# Conclusion

- Combining Sensorwebs with an elastic computation cloud enables surge capacity for disasters by enabling parallel processing of various algorithms and other processes within the cloud
- Elastic cloud provides work space for user to customize their experience instead of a preset outputs